

# The International Space Station Research Opportunities and Accomplishments

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**Abstract** - *In 2010, the International Space Station (ISS) construction and assembly was completed to become a world-class scientific research laboratory. We are now in the era of utilization of this unique platform that facilitates ground-breaking research in the microgravity environment. There are opportunities for NASA-funded research; research funded under the auspice of the United States National Laboratory; and research funded by the International Partners – Japan, Europe, Russia and Canada. The ISS facilities offer an opportunity to conduct research in a multitude of disciplines such as biology and biotechnology, physical science, human research, technology demonstration and development; and earth and space science. The ISS is also a unique resource for educational activities that serve to motivate and inspire students to pursue careers in Science, Technology, Engineering and Mathematics. Even though we have just commenced full utilization of the ISS as a science laboratory, early investigations are yielding major results that are leading to such things as vaccine development, improved cancer drug delivery methods and treatment for debilitating diseases, such as Duchenne's Muscular Dystrophy. This paper highlights the microgravity scientific research opportunities available on the ISS and the early results and accomplishments it is yielding.*

**Introduction** Almost as soon as the International Space Station was habitable, researchers began using it to study the effects of microgravity and other space effects on several aspects of our daily lives. Now 10 years later, this unique space research platform is open for business. The permanent presence of the ISS in a microgravity environment allows scientists to rapidly acquire the large sets of data necessary to validate new concepts. They can also make multiple experiment runs in succession, obtaining statistically significant results in a matter of weeks, even days, instead of years. The ISS also has a significant power, thermal and data capability allowing for the support of instruments that can image our Earth and observe the cosmos.

Over the next 10 years and lifespan of this microgravity research laboratory, we expect that knowledge gained from the ISS will lead to new scientific discoveries, the development and demonstration of technology for future space exploration and the generation of products that will spur our economy and benefit life on Earth.

**Research Opportunities** The objectives for research being done ISS falls into several areas. There is NASA-funded research that enables further human space exploration. This is research funded by the NASA Mission Directorates. The Human

Exploration and Operations Mission Directorate sponsors research in Physical and Life Sciences, Human Research and Exploration Research. Technology Development is sponsored by the Office of the Chief Technologist and the Science Mission Directorate supports Astrophysics, Heliophysics, Planetary and Earth Sciences research.

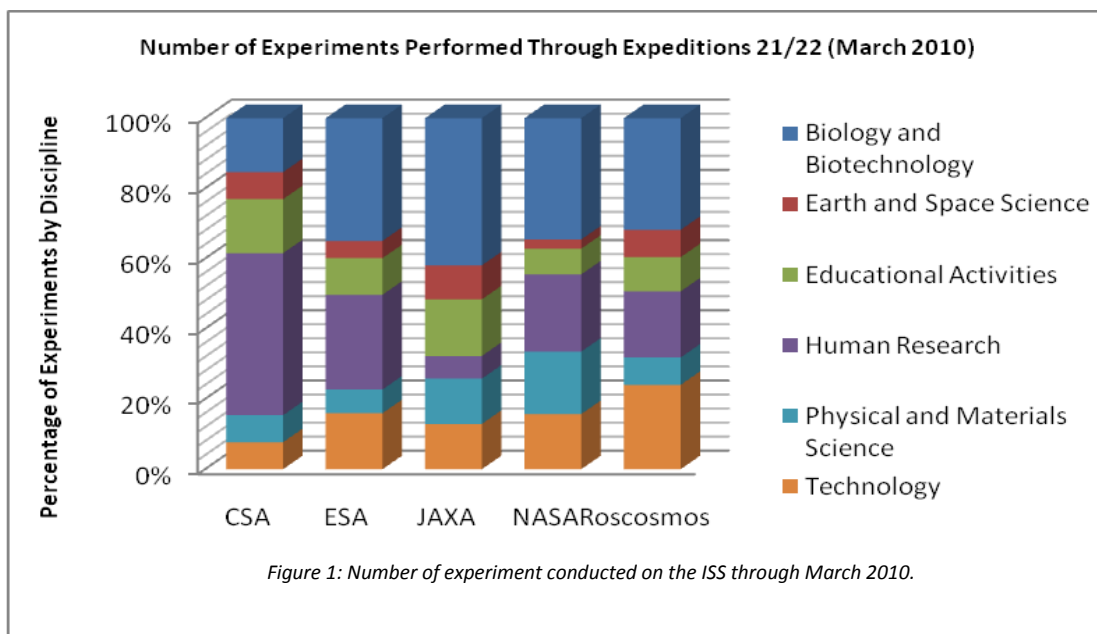
In 2005, the U.S. Congress designated a portion of the ISS as a National Laboratory (NL)<sup>1</sup>. The NL is utilized by U.S. commercial companies, non-profit organizations and other U.S. government agencies such as National Institutes of Health and the Department of Defense, to name a few. In 2010, the Center for the Advancement of Science in Space (CASIS) was afforded the opportunity to manage this US national asset with the goal of supporting, promoting and accelerating innovations and new discoveries in science, engineering and technology that will improve life on Earth.

Research is also sponsored by the International Partners – Canadian Space Agency (CSA), Japan Aerospace and

Exploration Agency (JAXA), European Space Agency (ESA) and the Russian Space Agency (ROSCOSMOS). This is research that supports the national goals of each partner nation.

The ISS has a unique ability to capture the imagination of both students and teachers worldwide. The permanent presence of humans onboard the ISS for the past ten years has provided a foundation for numerous educational activities aimed at capturing the interest of students and motivating study in sciences, technology, engineering and mathematics (STEM). Students have several pathways of participating in ISS research. They have the opportunity to develop experiments that are flown on the ISS, perform classroom versions of ISS experiments, participate in investigator experiments, compete in design challenges or access educational demonstrations that are performed by crewmembers and that serve as teaching aids.

Since the launch of the first ISS module in 1998, there have been 552 experiments conducted on the ISS with the participation



of 59 countries. For tracking and reporting purposes, these experiments are categorized by the following disciplines: biology and biotechnology, physical science, human research, technology development, earth and space science and education (see Figure 1).

*Biology and Biotechnology* The ISS has scientific capability to provide a unique laboratory to investigate biological or life sciences without the constraint of gravity. Some microgravity studies have observed increased virulence in microbial bacteria, pluripotency of stem cells, and tissue morphogenesis patterns. These early results have led to researcher's understanding of gene expression and biological response to microgravity that cannot be studied on Earth<sup>[2]</sup>.

*Human Research* The ISS to do extensive assessments on the human body and it's health that cannot be done on Earth. In the microgravity environment, humans exhibit a variation in effects on a number of physiological systems (bone and muscle loss; cardiovascular, immune and neurological changes, to name a few) and their response to potential countermeasures. The knowledge gained through these changes not only provide insight for future, safe, long duration space flight but also serve as good experimental models and analogs that can benefit human health on Earth<sup>[3]</sup>.

*Physical Sciences* Scientific investigations in the field of physical sciences allow researchers to better understand the dynamics of fluid flow that is driven by surface tension, combustion processes in the absence of buoyant convection (see Figure 2) and the studies of material melting and solidification process<sup>[4]</sup>.

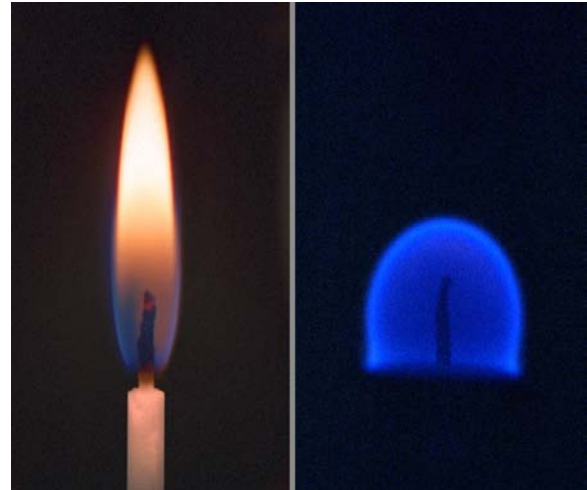


Figure 2: A candle flame in Earth's gravity (left) and microgravity (right) showing the difference in the process of combustion in microgravity. Image: Glenn Research Center (NASA)

*Technology Development* The ISS provides opportunities to test technologies needed for future human exploration of space. If we are to expand the human presence beyond low Earth's orbit, significant advances in technology must be made. The severe radiation space environment, the inability to rescue or evacuate crew in the event of emergencies, the lack of resupply, or the inability to refuel satellites are just some of the challenges faced by human space exploration. The Robotic Refueling Mission (RRM) is an example of a technology and tool that will be demonstrated and tested to robotically refuel satellites (Figure 3). The ISS serves as an excellent testing ground for space exploration technologies.

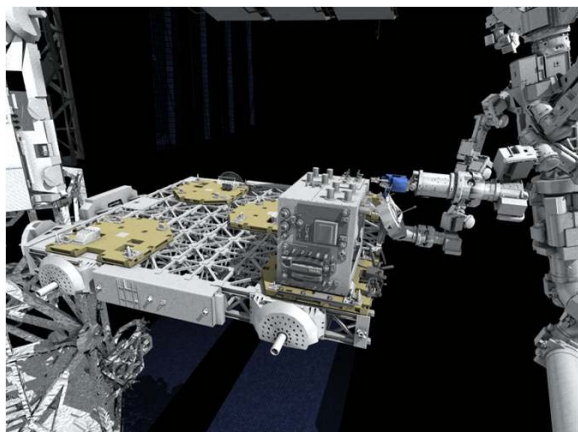


Figure 3: This artistic representation shows ISS's Dextre robot (right) performing a robotic refueling task on RRM (center), mounted to ELC4.

**Earth and Space Science** The ISS has a unique vantage point from which to observe the Earth and our cosmos. It orbits the Earth at an altitude of 220 km which allows it to cover 85% of the Earth's surface and 95% of the world's populated areas, every 1-3 days. As a result, the ISS is home to several Earth observation instruments and cameras that collect data and images which are used by scientists to study and record the changes taking place on Earth.

Researchers also have an opportunity to study the universe without the distortion of the Earth's atmosphere. The ISS provides a platform deployment of space science instruments that scan the skies in x-ray wavelengths and detects and characterizes high energy cosmic rays that can lead to the unanswered questions of our universe's origins.

**Research Accomplishments** Even before the full completion of the ISS, scientists have utilized about 20% of the station's research capability. These early investigations have already yielded great benefits that not only enable future space exploration but that impacts life on Earth. The following results are a few that

demonstrate the value of the ISS as a research laboratory.

**Microbial Vaccine Development** The *Microbe* investigation (Principal Investigator Dr. Cheryl Nickerson, Arizona State University)<sup>[5]</sup> studied the effects of microgravity on the virulence of three model microbial pathogens *Salmonella typhimurium* (See Figure 4), *Pseudomonas aeruginosa*, and *Candida albicans*. These pathogens had been identified as potential threats to crew health based upon previous space flight missions. The results showed that cells often propagate and exhibit different virulence levels and in the case of *Salmonella*, the virulence was increased. Researchers were also able to identify the controlling gene mechanism that was responsible for the increase bacterial potency. As a result, AstroGenetix, Inc., a U.S. commercial company has funded their own follow-on studies on ISS and are pursuing development of vaccines and therapeutic drugs to combat bacterial pathogens. They are seeking approval of a vaccine for *Salmonella* – a bacteria that causes food-poisoning in millions of people worldwide, as an Investigational New Drug

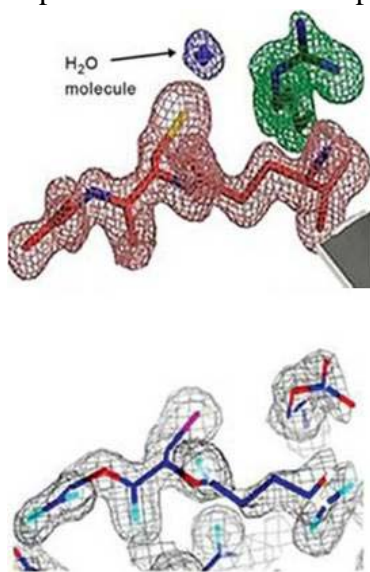


Figure 4: Image of *Salmonella typhimurium*, one of the three model bacterial pathogens examined for the *Microbe* investigation.. Image courtesy Rocky Mountain Laboratories



(IND) with the Federal Drug Administration. They are now applying a similar development approach to the methicillin-resistant *Staph aureus* (MRSA) which is accountable for almost 20,000 human deaths per year in the U.S. alone.

**Macromolecular Crystallization** Protein crystal growth investigations involves identifying the structures and functions of proteins, based on genes. By analyzing the structures of many different kinds of proteins and understanding how they interact with one another, it may become possible to identify various mechanisms involved in life phenomena. It could also be possible to inhibit or activate functions of certain proteins to develop new



*Figure 5 : Electron Density Maps of HQL-79 crystals grown in space show a more detailed three-dimensional structure (top) as compared to those grown on Earth (bottom), which also uncovered the presence of a newly identified water molecule. Figures courtesy of Yoshihiro Urade.*

pharmaceuticals. Under microgravity conditions, large biological macromolecules have been proven to form larger and more perfectly than on the ground. The absence of thermal convection, sedimentation,

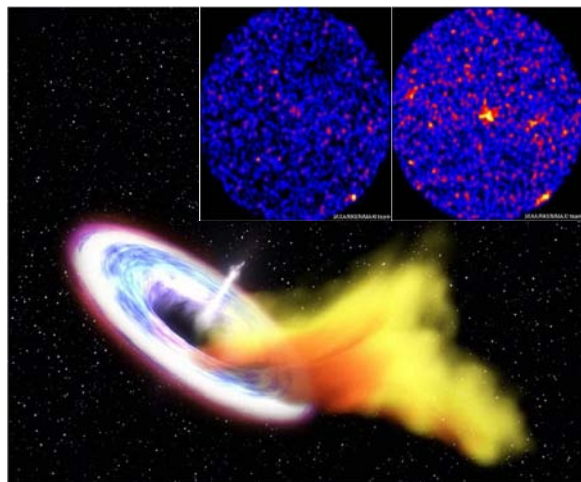
buoyancy, hydrostatic pressure and gradients inherent in the natural gravity environment all contribute to improved growth in the environment of space. Researchers from the Japanese Aerospace Exploration Agency (*JAXA-GCF*. Principal Investigator: H. Tanaka, Japan Space Forum, Tokyo, Japan) in a collaboration with Russian scientists flew and crystallized HQL-79 (Hematopoietic prostaglandin D synthase inhibitor protein)<sup>[6]</sup>. They identified an improved three-dimensional structure and an associated water molecule that was not previously identified in ground models. This improved HQL-79 protein (Figure 5) is part of a candidate treatment for inhibiting the effects of Duchenne's muscular dystrophy<sup>5</sup>, a debilitating degenerative disease that affects 1 in 3000 boys under the age of 9 years old. HQL-79 is an excellent lead compound for the development of novel protein inhibitors that promise to be new concept drugs against a variety of other allergic and non-allergic diseases.

**ECLSS Regeneration** At the micro level of environmental sciences, ISS represents among the most sophisticated engineering test beds in the world for oxygen regeneration and water reclamation. A urine processor assembly handles up to 23.2 pounds of condensate, crew urine, and urinal flush water to produce a purified distillate. This distillate is combined with other wastewater sources collected from the crew and cabin and is processed, in turn, by a water processor assembly (WPA) to produce drinking water for the crew. The WPA will process a nominal rate of 48.8 pounds of wastewater per day. A portion of the potable water that is produced is used as feed water to an oxygen generation assembly (OGA). The OGA, in turn, electrolyzes potable water into oxygen and hydrogen byproducts. The oxygen is

delivered to the cabin at a selectable rate of 2.3-9.1 kg (5-20 lbs) of oxygen per day.

The resin used in the microbial check valves in the NASA water processor assembly have now been developed as a commercial water filtration solution by Water Security Corporation, and can be used anywhere in the world there are water quality problems. The commercial system requires little maintenance, no electricity, and provides water that remains safe to drink. These systems have been deployed in disaster and humanitarian relief situations in a number of countries including Mexico, Iraq, and Pakistan.

*X-Ray Monitoring* The ISS is the home to MAXI (Principal Investigator: M. Matsuoka, Institute of Space and Astronautical Science (ISAS) ISS Science Project Office, Japan Aerospace Exploration Agency, Tsukuba, Japan), a highly sensitive X-ray camera, that is externally mounted and is designed to



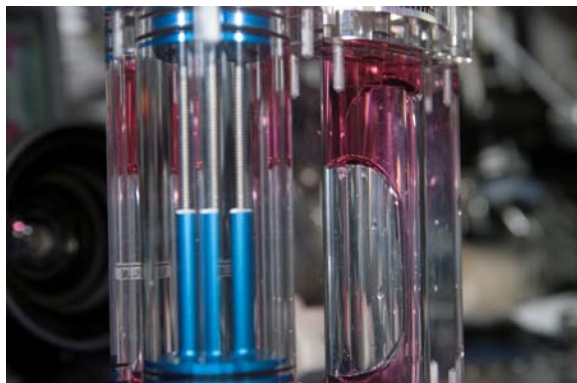
*Figure 6: Image of black hole devouring a star and x-ray detections made by the ISS instrument MAXI. Image courtesy of Japan Aerospace Exploration Agency.*

monitor more than 1000 X-ray sources in space over an energy band range of 0.5 to 30 keV. The x-ray sources include black holes, supernovas remnants and stars, to name a

few. MAXI monitors the X-ray variability once every 96 minutes covering the entire sky on time scales from a day to a few months. As an all-sky monitor, MAXI employs slit cameras. They determine one direction of X-ray sources within the narrow field of view of the slit that is orthogonally oriented to a one-dimensional position-sensitive X-ray detector. In 2010, MAXI along with the SWIFT instrument detected bright X-ray flare from the extragalactic transient. It was the first observation by both instruments of the onset of a relativistic x-ray burst from a supermassive black hole. This is attributed to the disruption of a star falling into the black hole and creating a jet of x-rays<sup>[7]</sup> (Figure 6). The observations of this instrument and other like it, contribute to the expansion of our fundamental knowledge of our universe.

*Fluid Flow* On Earth, fluid flow in containers is dictated by the presence of hydrostatic pressure. The effect of capillary forces is limited to a few millimeters. In microgravity, there is no hydrostatic pressure so fluids tend to climb container walls and capillary forces extend over meters. The Capillary Flow Experiment (Principal Investigator: Mark Weislogel, Portland State University) experiments on the ISS are a suite of fluid physics experiments that examine the flow of liquids in several capillary geometries<sup>[8]</sup>. Studying a variety of capillary dominated flow is key to spacecraft systems design that cannot be studied on the ground. Currently, the fuel tanks of spacecrafts are designed with additional reservoir to prevent the gas bubbles that form, from ingesting into the engines during firings. Current computational models do not accurately predict the maximum flow rate that is achievable through the vanes of the capillaries. The CFE experiment was designed to test the theoretical predictions

for the free surface shapes and flow velocities for capillary vane flows in



*Figure 7: NASA Image ISS015E10587 View of Capillary Flow Experiment (CFE) in the U.S. Laboratory/Destiny. The purpose of this experiment is to investigate capillary flows and phenomena onboard the International Space Station (ISS). A video camera is set up to record the behavior of silicone oil in the Contact Line (CL) unit. Photo was taken during Expedition 15.*

microgravity (see Figure 7). The results are immediately useful for the verification and validation of liquid management systems of present and future spacecrafts.

**Education Outreach** The International Space Station has a unique ability to capture the imaginations of both students and teachers worldwide. The presence of humans onboard ISS for the past ten years has provided a foundation for numerous educational activities aimed at capturing that interest and motivating study in the sciences, technology, engineering and mathematics (STEM). Students engagement are diverse and fall in several categories. There are student-developed experiments (see Figure 8) which are performed by students under the aegis of a teacher or scientist mentor, are performed solely for the benefit of students; classroom versions of ISS experiments; students who participate in ISS Investigator experiments; students who participate in ISS engineering education and hardware development and ISS on-orbit demonstrations that serve as teaching aids

for students. There have been over 900,000 students from the United States and over 31 million students worldwide, who have participated in ISS educational demonstrations performed by crewmembers onboard ISS<sup>[9]</sup>.



*Figure 8: Astronauts Cady Coleman and Ron Garan perform the Attracting Water Drops experiment from Chabad Hebrew Academy in San Francisco.*

**Conclusion** The era of utilization for the ISS has just begun but we have already had some amazing accomplishments. From the engineering and technological achievement of assembling the ISS to the international corporation of many nations working together to overcome their political challenges. Resulting in a world-class research laboratory that has the potential for new discoveries and applications that will advance our scientific knowledge and produce many benefits for life on Earth.

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